Organic fertilisation and the health effects of fruits and vegetables

Kirsten Brandt
School of Agriculture, Food and Rural Development
Newcastle University, UK

IOFGA Conference September 2008

Organic fertilisation and the health effects of fruits and vegetables

- How soil fertility affects plant composition to optimise plant health
  - Antioxidants
  - Secondary metabolites
- Predicted consequences for human health
  - Antioxidants
  - Secondary metabolites

Newcastle University

Antioxidants

Types and roles in plants:

- Vitamin C:
  - involved in redox regulation (same as in animals)
- Vitamin E:
  - protect lipids against oxidation
- Phenolic compounds:
  - protect against UV-damage
  - (serve as pigments)
  - (involved in defence against pests and diseases)
- Carotenes:
  - involved in photosynthesis, protect against photooxidative stress
  - (serve as pigments)

Newcastle University

Antioxidants

- If soil nitrate availability is less than a plant's maximum uptake rate → "moderate N-stress"
  - Plant metabolism → ↑ N-use efficiency
  - ↓ number of chloroplasts
    - ↓ accumulation of carotenoids
  - Smaller, thicker leaves
    - ↓ accumulation of UV-protective phenolics
  - ↑ oxidative stress
    - ↑ accumulation of vitamin C
  - ↑ oil content compared with protein
    - ↑ Vitamin E(?)

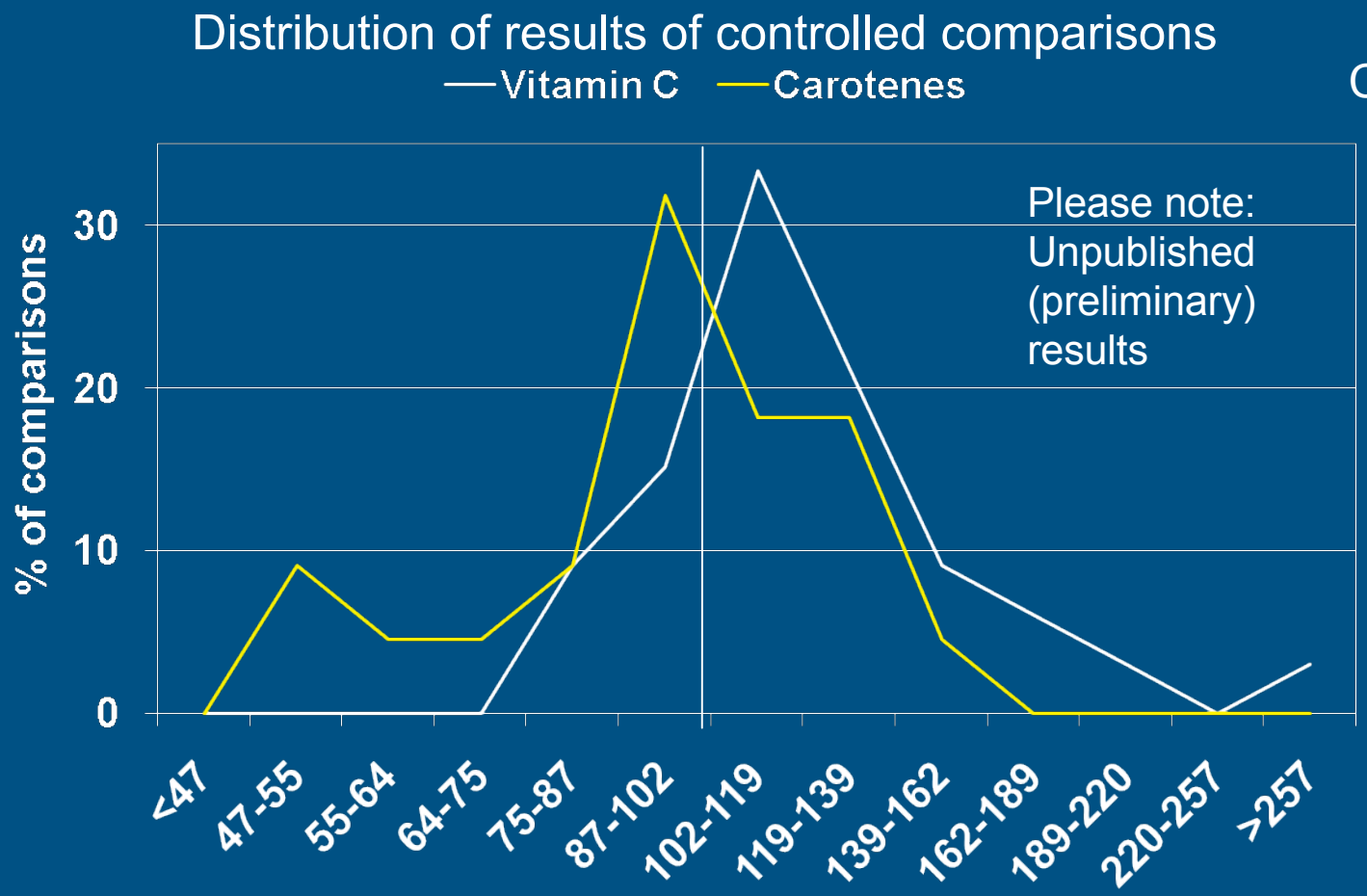
Newcastle University

Antioxidants

- Organic fertilisation strategies cause nitrate to be released slowly in the soil, resulting in a relatively low nitrate availability
- Due to this, organic plant products contain relatively
  - more vitamin C
  - less carotenoids
  - different composition of phenolic compounds
  - more vitamin E?

Newcastle University

Antioxidants



Comparisons are:

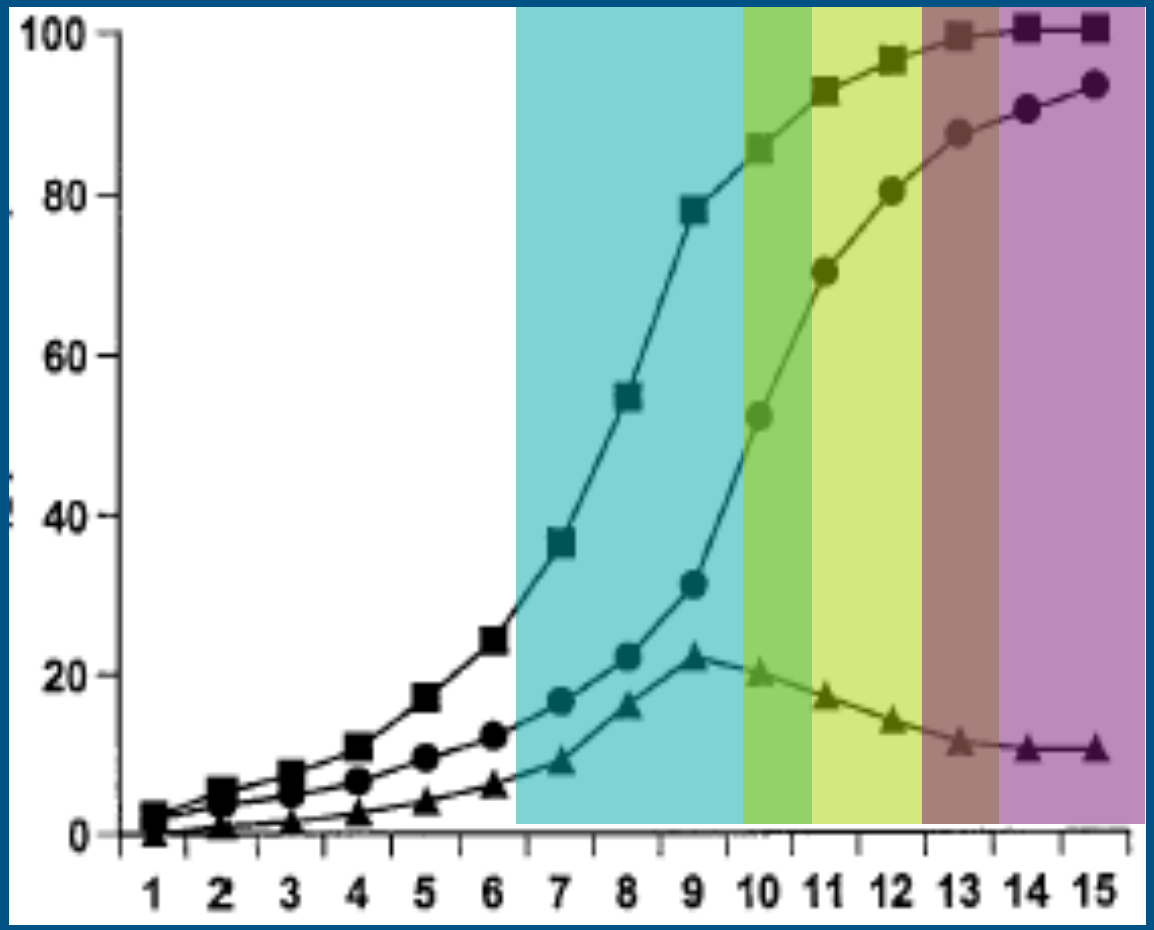
- fruits, herbs and vegetables
- same varieties
- same year
- same place
- (relevant organic and conventional commercial practice)
- on fresh weight basis

Average of all studies: Vitamin C: 117 % (32 comparisons)

Carotenes: 93% (22 comparisons)

Newcastle University

Defence-related secondary metabolites and fertilisation



Resource availability, e.g. soluble N

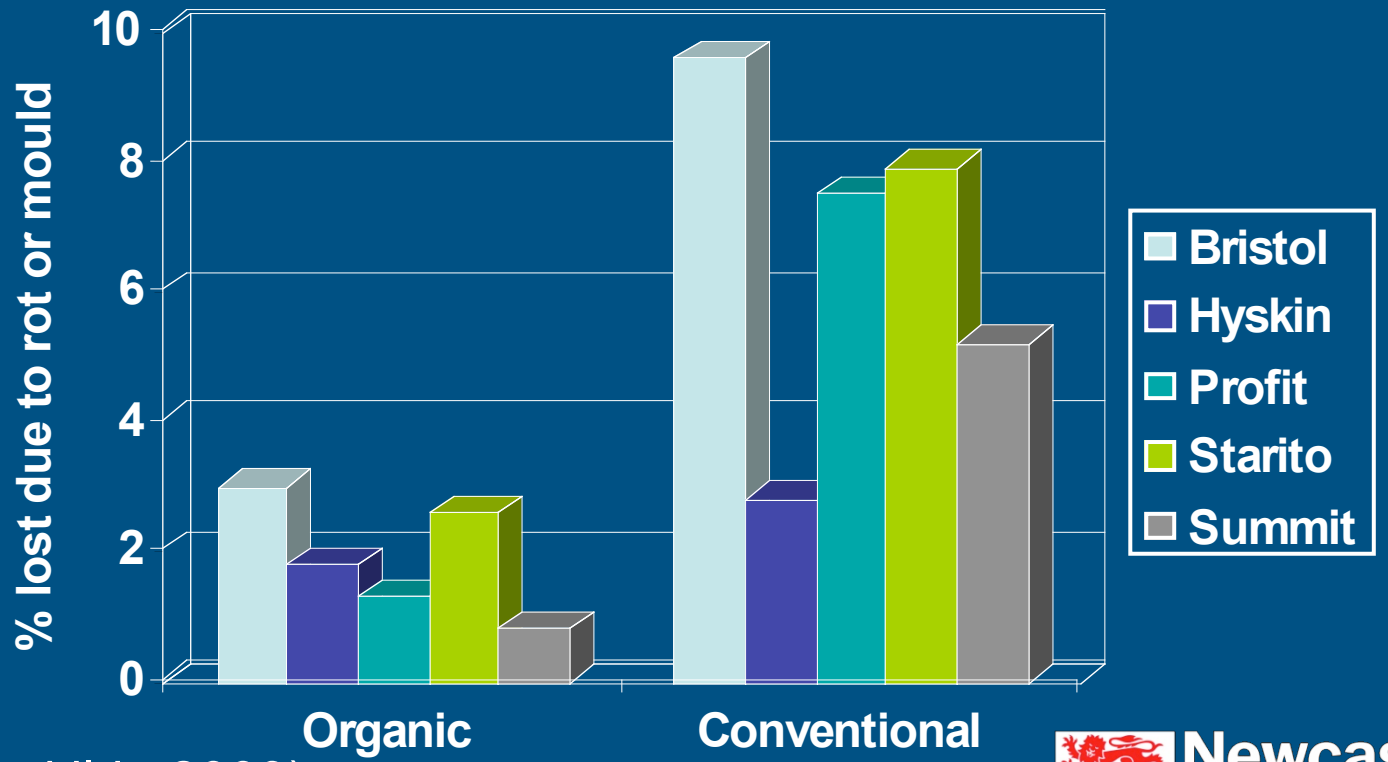
(graph from Stamp 2003)

- Plant mass
- Differentiated mass
- Subsistence farming
- Organic/low input
- Conventional /high input
- Secondary metabolites

Newcastle University

Effect of production system on resistance to disease

Effect of growing conditions on incidence of storage diseases in onion varieties



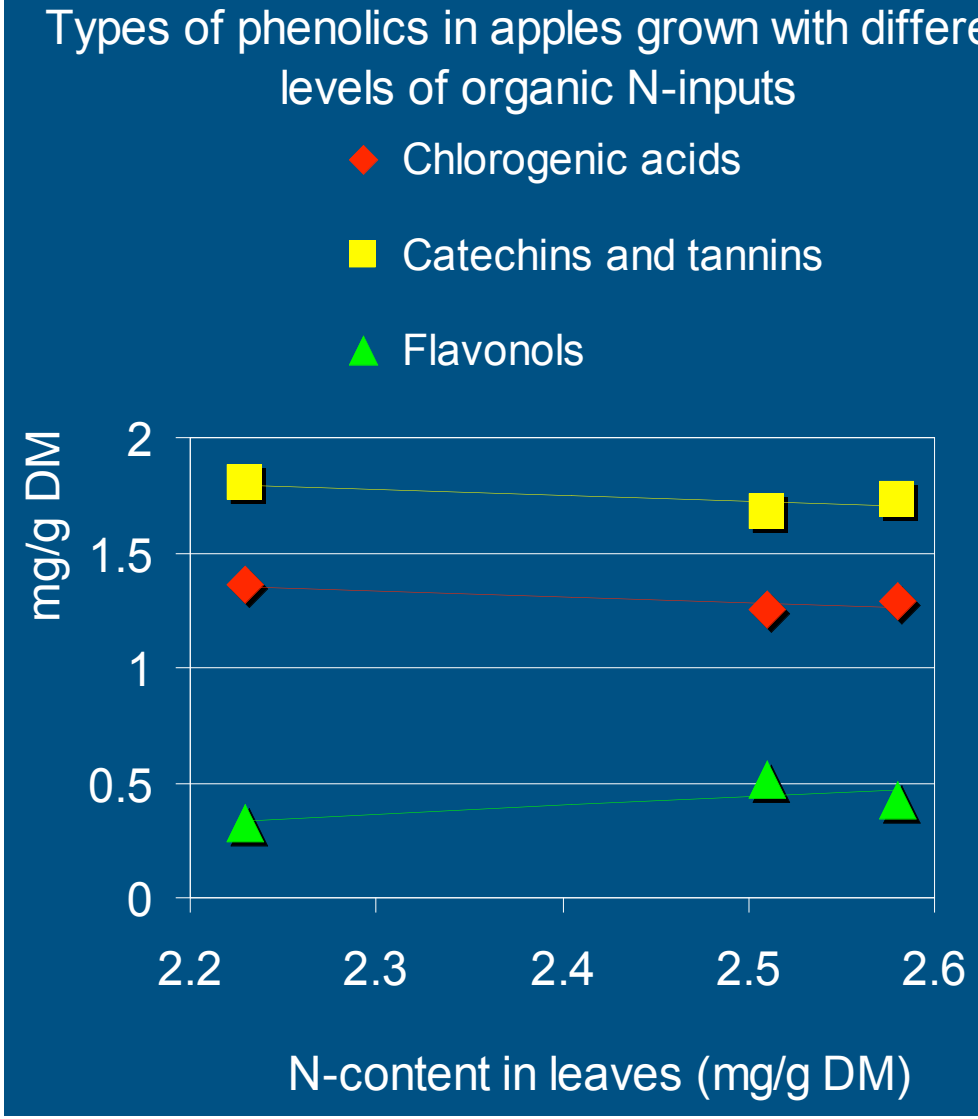
(Bjørn & Fruekilde 2003)

IOFGA Conference September 2008

Newcastle University

Phenolic compounds in apples

Types of phenolics in apples grown with different levels of organic N-inputs



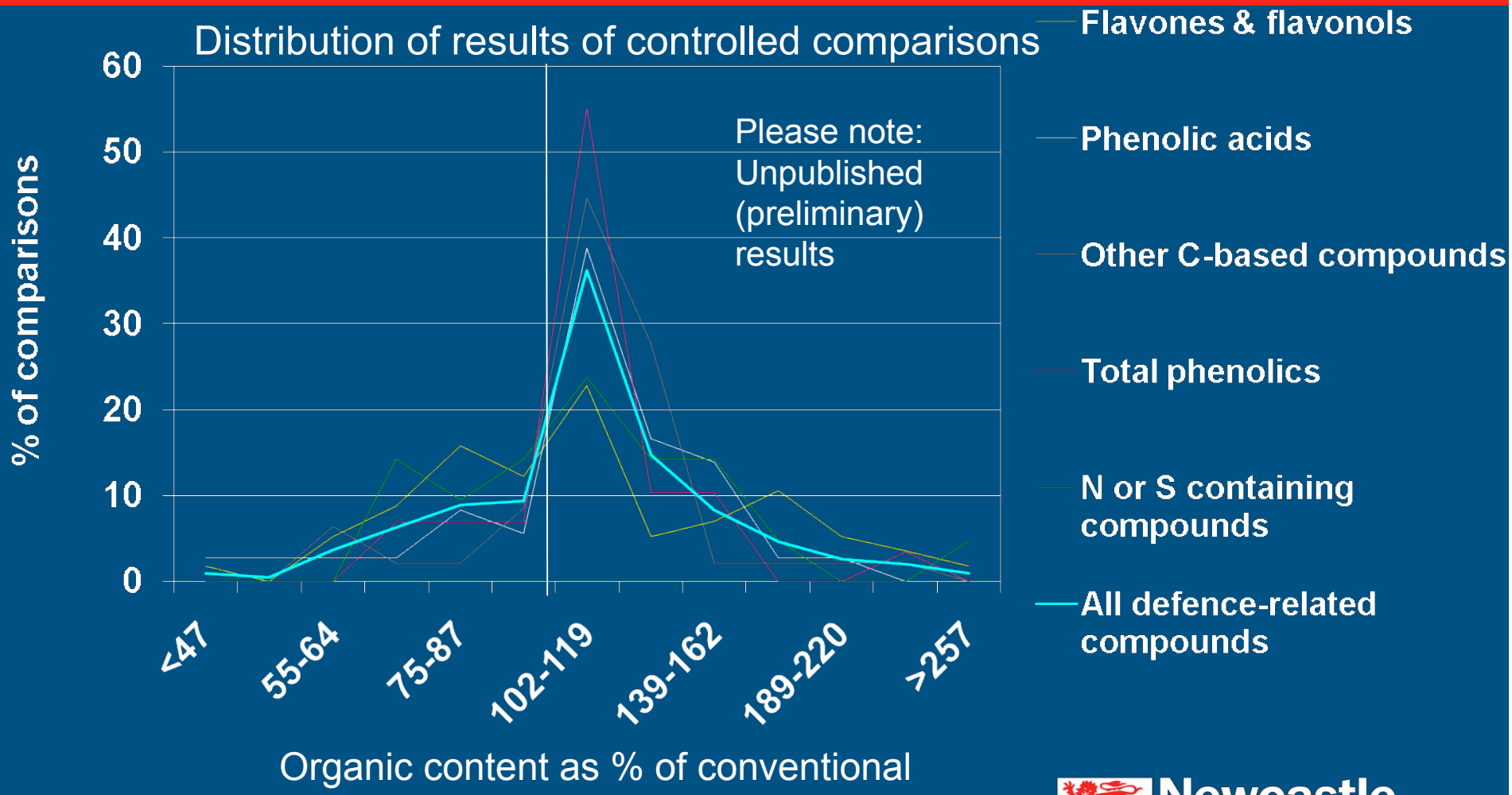
Chlorogenic acids, catechins and tannins defend the fruit against pests and diseases.

In contrast, the probable primary role for flavonols in apples are as UV-protective antioxidants

(data from Brandt et al. 2003)

Newcastle University

Secondary metabolites



Average of all compounds and studies: 110 %
(189 comparisons)

Newcastle University

Predicted consequences for human health

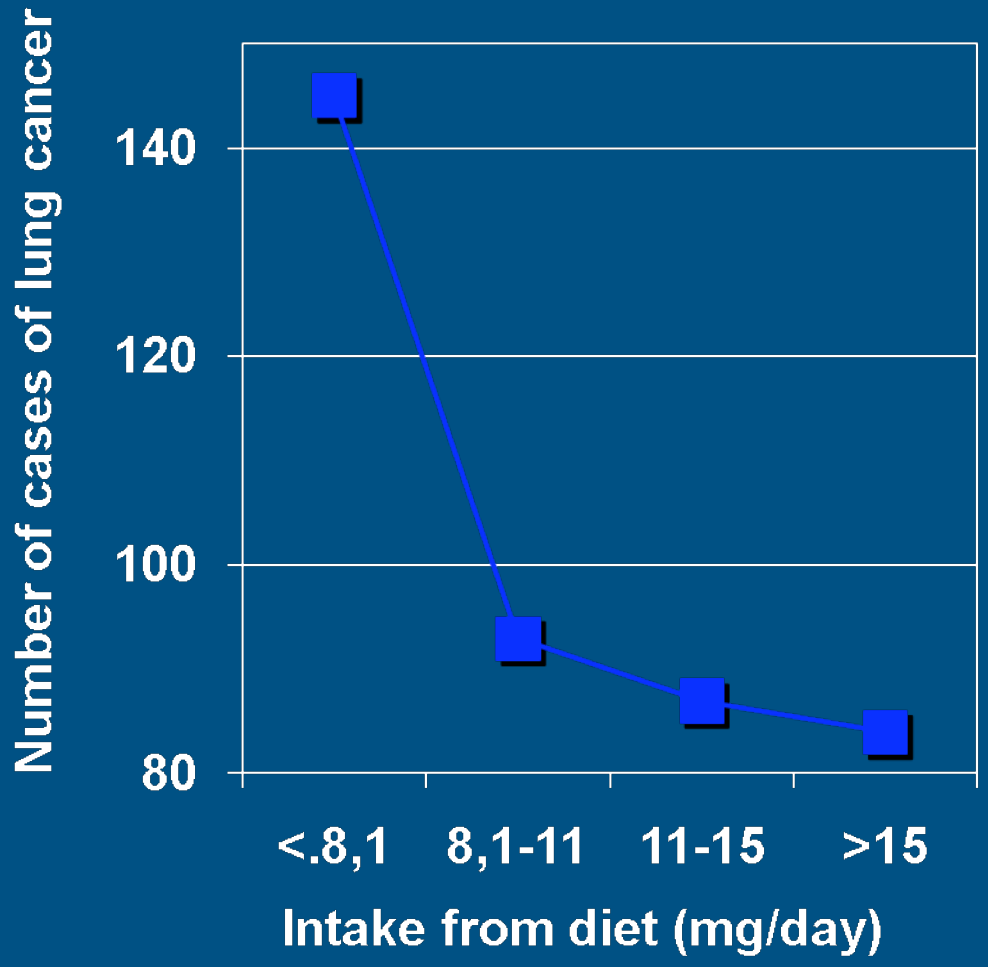
When is a moderate difference in content of a food compound important for human health?

1. The food must provide a large contribution to the dietary intake of this compound
2. The intake must be in a range where a change in intake of this compound affects health
3. Depending on this range, the effect can be beneficial or detrimental to health

Newcastle University

Predicted consequences for human health

Effect of vitamin E in the diet on risk of lung cancer



Each data point represents 3380 male smokers for 6 years.

People with very low vitamin E intake tend to have a generally unhealthy diet

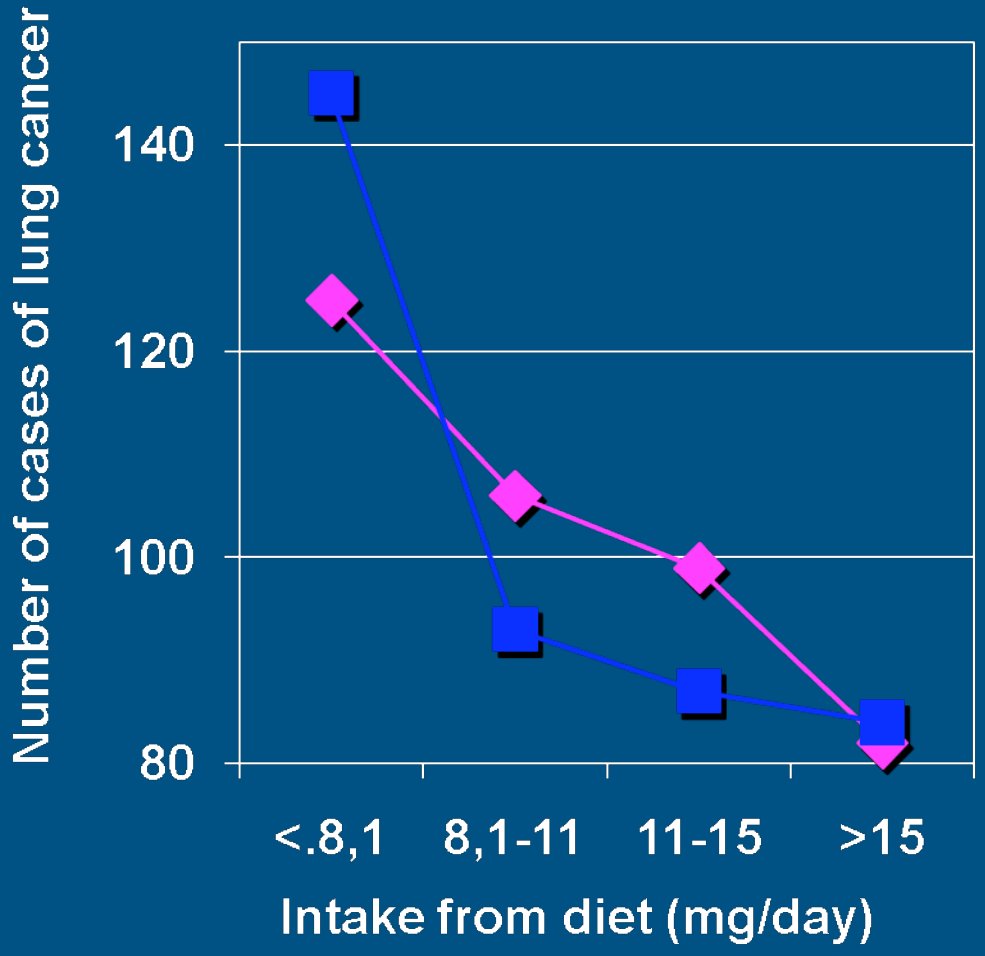
Data from Albanes et al. 1996

IOFGA Conference September 2008

Newcastle University

Predicted consequences for human health

Effect of vitamin E supplementation on risk of lung cancer



- Supplements can benefit health for those with a very poor diet, who are really deficient in the nutrient
- Supplements provide no benefit if the diet contains enough of the nutrient to prevent deficiency

IOFGA Conference September 2008

Newcastle University

Effect of increased intake of fruits and vegetables on human health

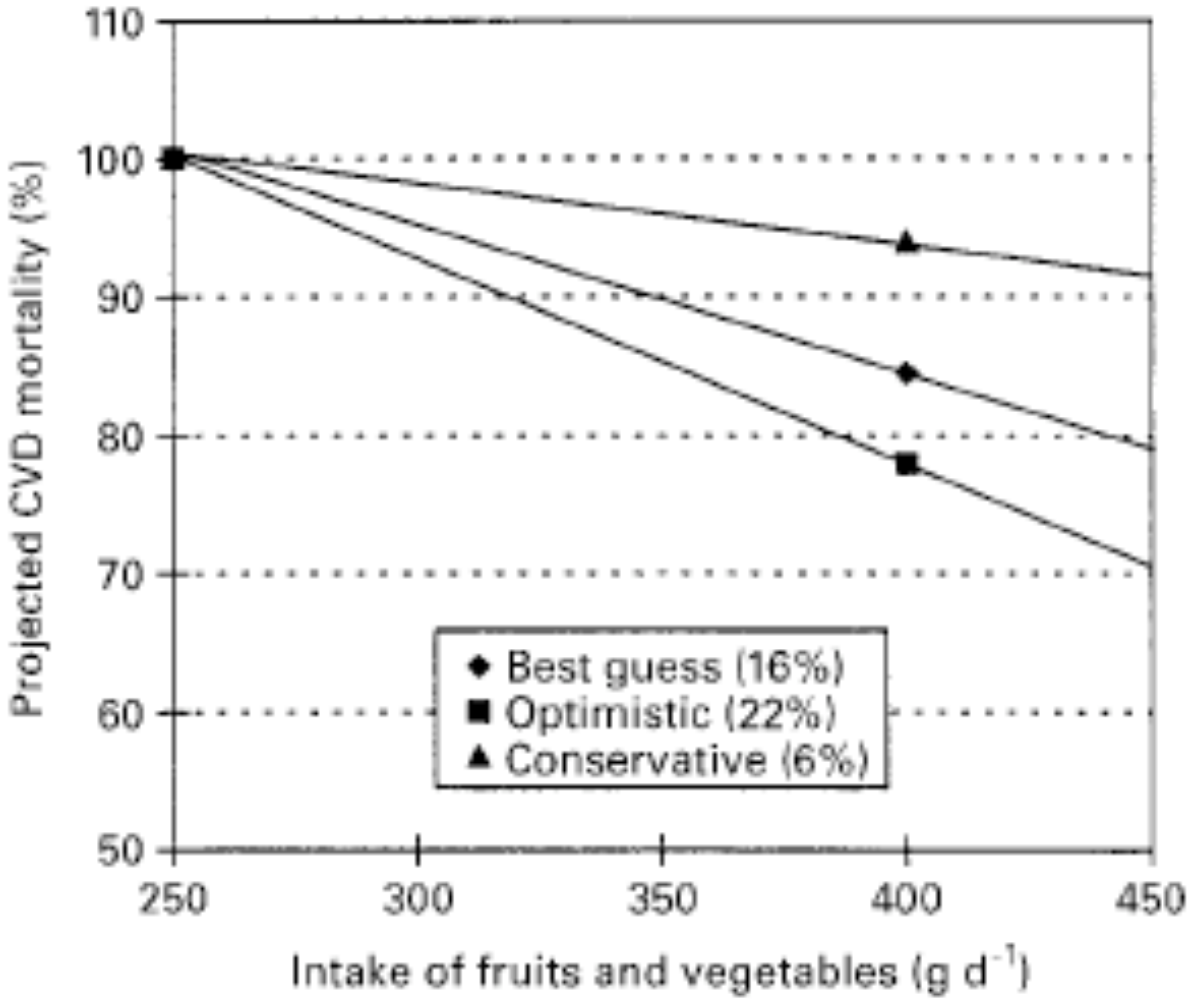
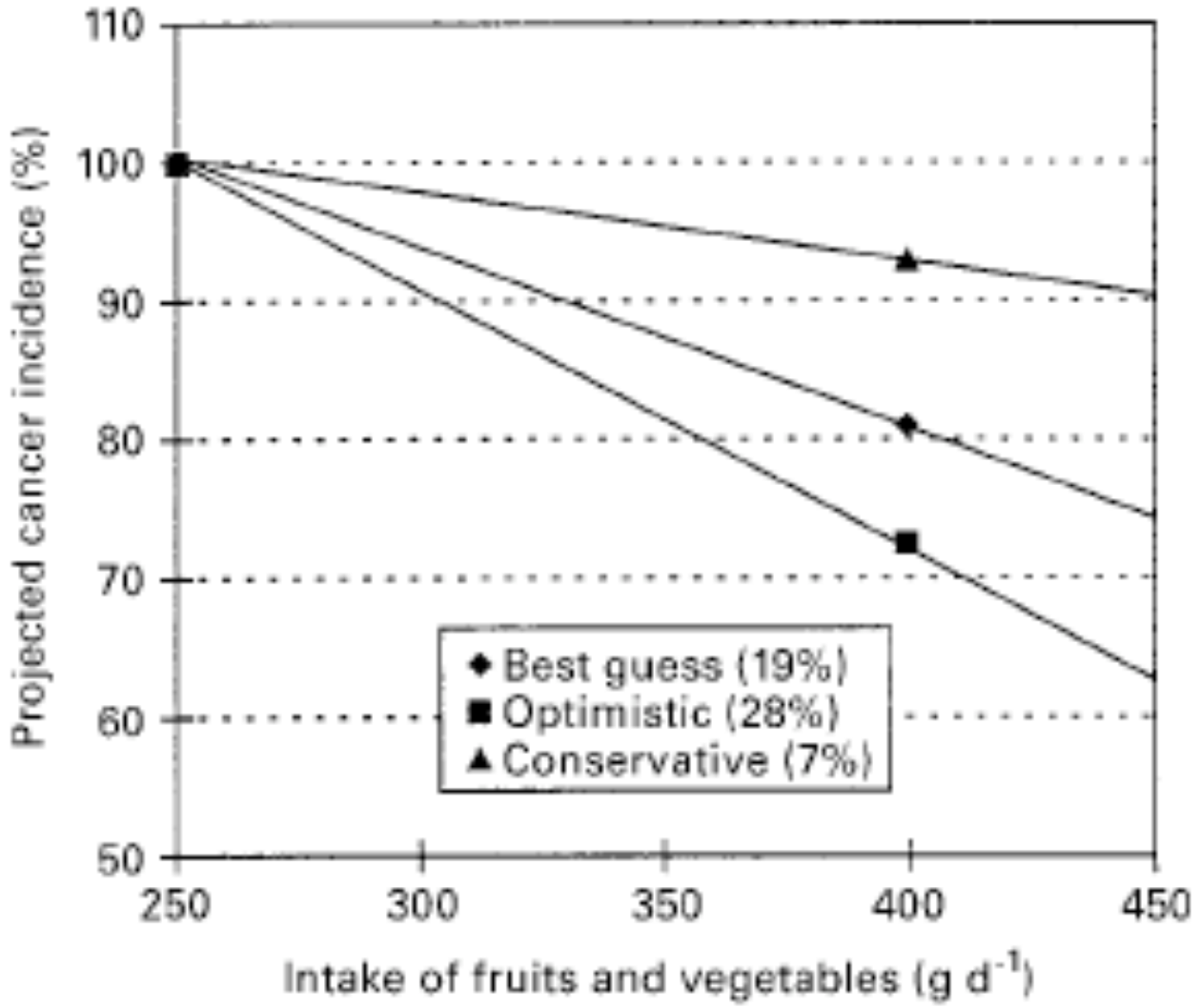


Fig. 1 Preventable proportion of chronic diseases as related to the intake of fruits and vegetables

(van't Veer et al. 2000)

Effect of increased intake of fruits and vegetables on human health



(van't Veer et al. 2000)

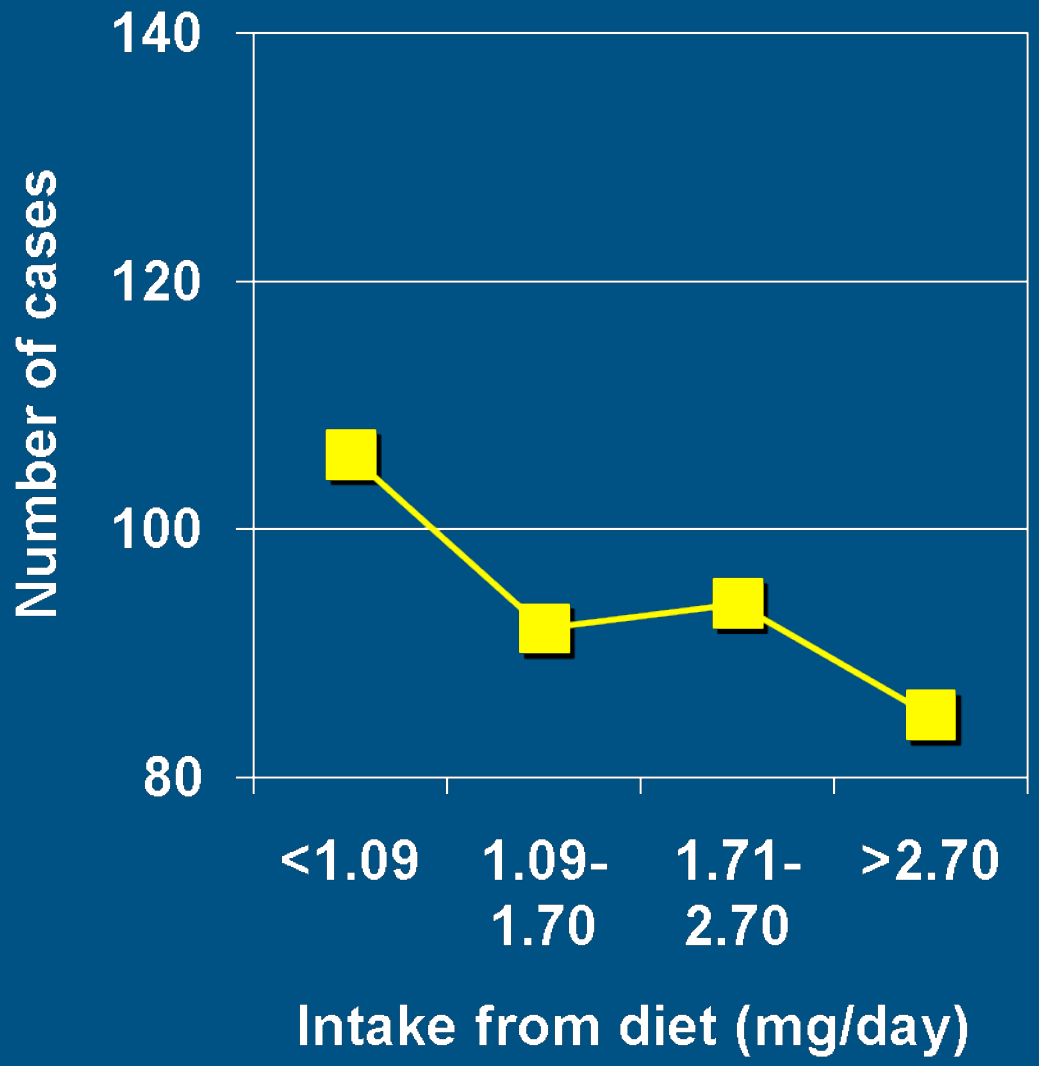
Which dietary compounds mostly come from fruits and vegetables?

- Vitamin C (but also used as food additive)
- Carotenes such as beta-carotene, lycopene
- Secondary metabolites
- Pesticide residues (in conventional F&V)
- Nitrate (mainly vegetables)

- To find out which ones are important for health, it is necessary to do intervention studies with each compound at a time

Newcastle University

Effect of beta-carotene intake on lung cancer risk



Each data point represents 3380 male smokers for 6 years.

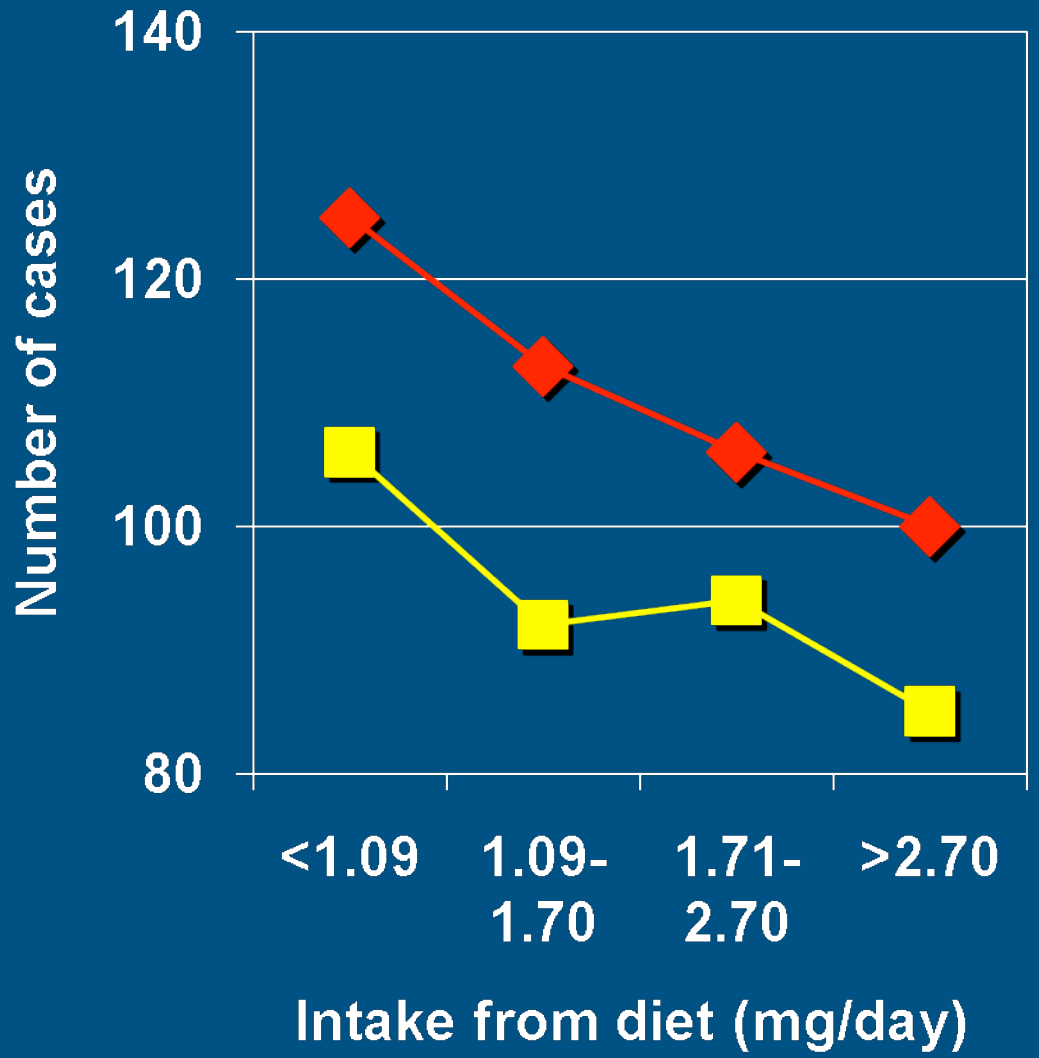
The intake of dietary beta-carotene is closely correlated with intake of its main dietary source, carrots.

Data from Albanes et al. 1996

IOFGA Conference September 2008

Newcastle University

Effect of beta-carotene supplementation on lung cancer risk



Each data point represents 3380 male smokers for 6 years.

The lack of interaction shows that the benefit of foods containing beta-carotene is due to another compound.

Data from Albanes et al. 1996

IOFGA Conference September 2008

Newcastle University

Effects of antioxidant supplementation on health

Mortality in Randomized Trials of Antioxidant Supplements for Primary and Secondary Prevention

Systematic Review and Meta-analysis

Goran Bjelakovic, MD, DrMedSci
Dimitrinka Nikolova, MA
Lise Lotte Gluud, MD, DrMedSci
Rosa G. Simonetti, MD
Christian Gluud, MD, DrMedSci

Context Antioxidant supplements are used for prevention of several diseases.

Objective To assess the effect of antioxidant supplements on mortality in randomized primary and secondary prevention trials.

Data Sources and Trial Selection We searched electronic databases and bibliographies published by October 2005. All randomized trials involving adults comparing beta carotene, vitamin A, vitamin C (ascorbic acid), vitamin E, and selenium either singly or combined vs placebo or vs no intervention were included in our analysis. Randomization, blinding, and follow-up were considered markers of bias in the included trials. The effect of antioxidant supplements on all-cause mortality was analyzed with random-effects meta-analyses and reported as relative risk (RR) with 95% confidence intervals (CIs). Meta-regression was used to assess the effect of covariates across the trials.

Data Extraction We included 68 randomized trials with 232 606 participants (385 publications).

Data Synthesis When all low- and high-bias risk trials of antioxidant supplements were pooled together there was no significant effect on mortality (RR, 1.02; 95% CI, 0.98-1.06). Multivariate meta-regression analyses showed that low-bias risk trials (RR, 1.16; 95% CI, 1.05-1.29) and selenium (RR, 0.998; 95% CI, 0.997-0.9995) were significantly associated with mortality. In 47 low-bias trials with 180 938 participants, the antioxidant supplements significantly increased mortality (RR, 1.05; 95% CI, 1.02-1.08). In low-bias risk trials, after exclusion of selenium trials, beta carotene (RR, 1.07; 95% CI, 1.02-1.11), vitamin A (RR, 1.16; 95% CI, 1.10-1.24), and vitamin E (RR, 1.04; 95% CI, 1.01-1.07), singly or combined, significantly increased mortality. Vitamin C and selenium had no significant effect on mortality.

Conclusions Treatment with beta carotene, vitamin A, and vitamin E may increase mortality. The potential roles of vitamin C and selenium on mortality need further study.

JAMA. 2007;297:842-857 www.jama.com

OXIDATIVE STRESS IS IMPLICATED in most human diseases.[1,2] Antioxidants may decrease the oxidative damage and its alleged harmful effects.[3-6] Many people are taking antioxidant supplements, believing to improve their health and prevent diseases.[7-10] Whether antioxidant supplements are beneficial or harmful is uncertain.[11-15] Many primary or secondary prevention trials of antioxidant supplements have been conducted to prevent several diseases.

We found that antioxidant supplements, with the potential exception of selenium, were without significant effects on gastrointestinal cancers and increased all-cause mortality.[14,15]

Antioxidants with no effect on mortality:

- vitamin C
- selenium

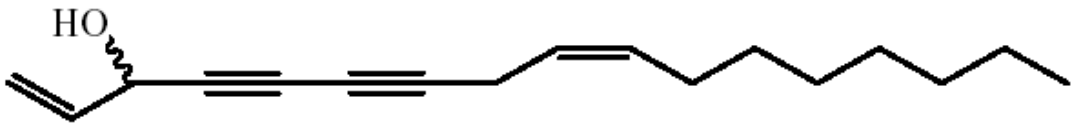
Antioxidants that significantly increase mortality:

- vitamin A
- beta-carotene
- vitamin E

Newcastle University

Identification of health-promoting compounds in plant foods

- Carrots are not only a source of beta-carotene. They are also the major dietary source of the polyacetylene falcarinol, a secondary metabolite
- Korean scientist have found that falcarinol from ginseng is a possible anti-cancer compound
- Falcarinol is a natural pesticide with strong biological activity



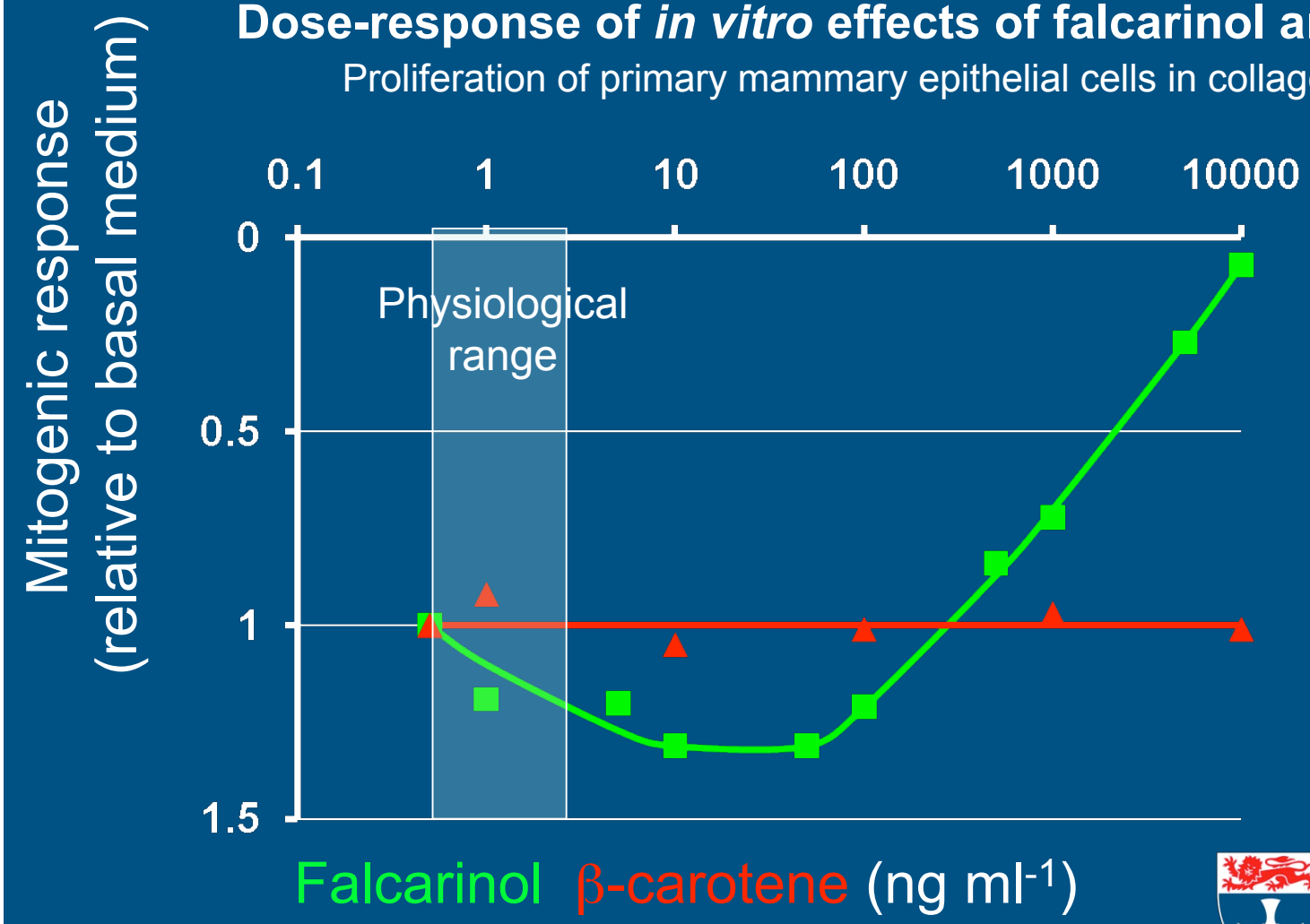
Falcarinol

Newcastle University

Identification of health-promoting compounds in plant foods

Dose-response of *in vitro* effects of falcarinol and β-carotene

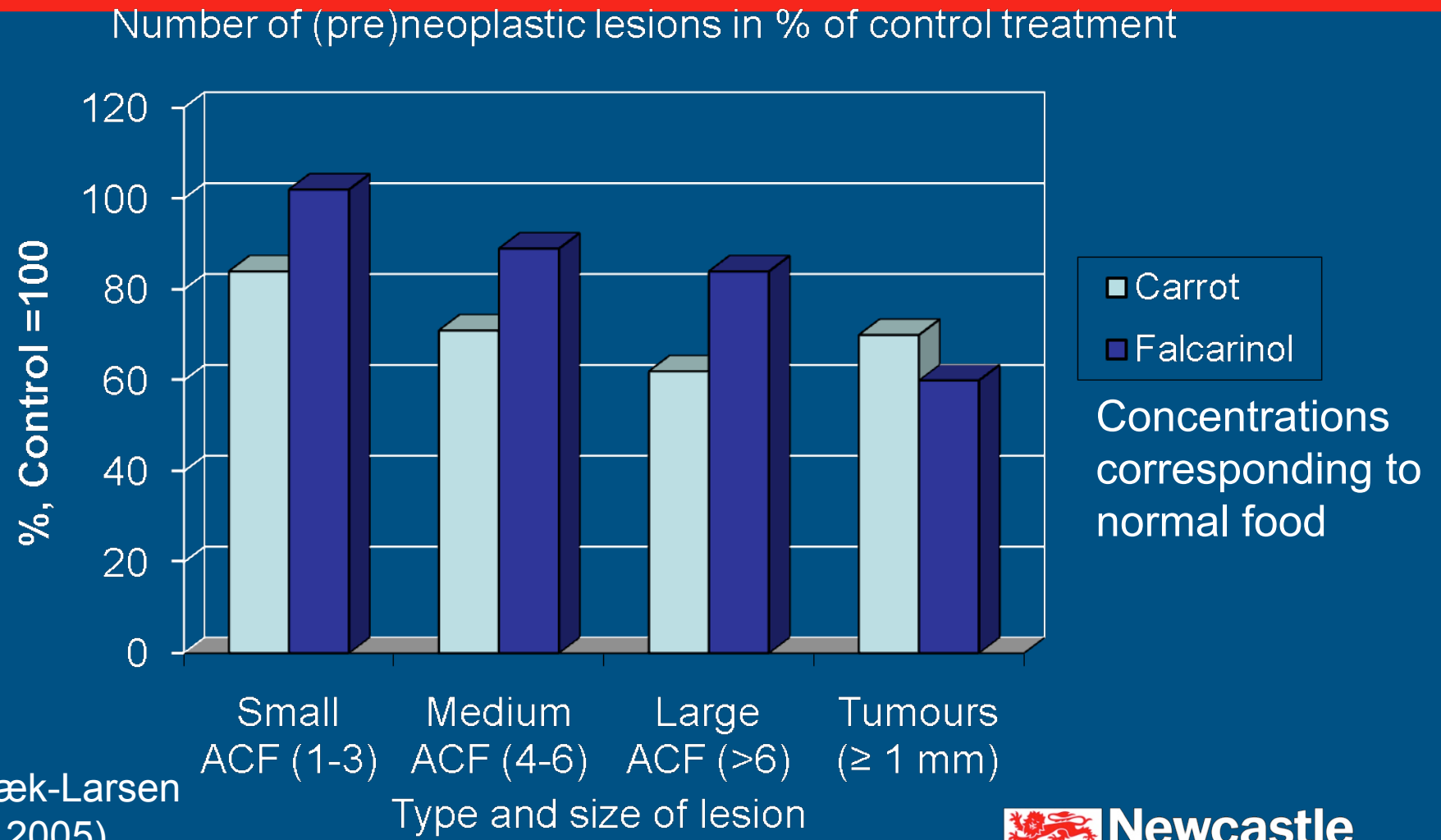
Proliferation of primary mammary epithelial cells in collagen gel cultures.



IOFGA Conference September 2008

Newcastle University

Effect of carrots and a carrot secondary metabolite on Azoxymethane induced colorectal cancer in rats



Concentrations corresponding to normal food

(Kobæk-Larsen et al. 2005)

IOFGA Conference September 2008

Newcastle University

Predicted consequences for human health

- Antioxidants
  - No studies have shown any benefits of increased intake in populations with adequate vitamin intake
  - For vitamin C, no significant increase in risk
  - For vitamin E and beta-carotene, moderate % change in intake causes a small increase in disease risk
  - 20% increase in lung cancer risk by 700% increased intake of beta-carotene
  - 3% increase in overall mortality by 2000% increased intake of vitamin E

Predicted consequences for human health

- Secondary metabolites
  - Only type of potentially health-promoting compounds that are exclusive to plant foods and mainly occur in both fruits and vegetables
  - 16% reduction in CVD risk and 19% reduction in cancer risk by 60% increased intake of F&V

Newcastle University

Predicted changes in intake by switching to organic fruits and vegetables

- Antioxidants
  - Vitamin C: +5-10%
  - Carotenes: -5%
- Secondary metabolites
  - All subgroups for which data is available: +10%

Newcastle University

Predicted changes in disease risk when switching to organic F&V

- Antioxidants
  - Vitamin C: 0% change in disease risk
  - Beta-carotene: 5% reduction in intake → 0.15% reduction in smokers' lung cancer risk
    (700% increased intake → 20% increased risk)
- Does this matter?
  - It is based on a linear extrapolation, which probably is not relevant (only for smokers who already take beta-carotene supplements)
  - Small numbers > 5 deaths/year in UK
  - F&V also contains protecting substances

Predicted changes in disease risk when switching to organic F&V

- Secondary metabolites
  - 10% increase in intake → 2.7% reduction in CVD risk and 3.2% reduction in cancer risk

    (60% increased intake → 16% reduction in CVD and 19% reduction of cancer)

Please note: Unpublished (preliminary) results

- Does this matter?
  - Experimental data indicate that this relation is linear in the relevant interval
  - Would correspond to approx. 10000 deaths per year in the UK

Newcastle University

Predicted consequences for human health

- Key assumption (testable):
  - That most of the health benefits of F&V intake are due to defence-related secondary metabolites
- Known omissions, which may change conclusions:
  - Potential health benefits of nitrate or of pesticide residues
  - Effects of fibres and folate

Newcastle University

Effect of organic farming methods on the health of those who consume the food

Conclusions

- Organic and conventional plant food production methods result in consistent compositional differences
- Some of these differences are large enough to potentially significantly benefit consumer health
- Improved understanding of these mechanisms is necessary to quantify, preserve and increase the benefits
- If we develop the organic fertilisation strategies to provide as much nitrogen as the conventional fertiliser, then we will lose health benefits for both plants and consumers

Support is gratefully acknowledged from:

- EU Commission, via the FP6 Integrated Project QualityLowInputFood (www.qlif.org)
- Danish Research Centre for Organic Farming (www.darcof.dk)

Newcastle University


Thank you for your attention!
Questions, comments?